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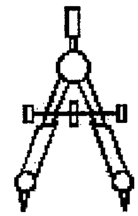
Measuring Celestial Dimensions with Micrometers



By: Jeff Beish

Association of Lunar and Planetary Observers (A.L.P.O.)

To find the linear size of celestial objects with a telescope one must use a measuring device such as a micrometer. Micrometers are usually made with adjustable webs, needlepoints, or an eyepiece reticle with graduated lines ruled in the glass. The webs, needlepoints, or reticle lines are positioned at the focal plane, in focus with the image, and magnified. An image can be aligned between the micrometer webs, points, or the ruled lines of the reticle and the separation noted on a dial or scribed on the reticle in either fractions of an inch or millimeters (See Figures 1 - 3).

To translate this separation to some usable angle or linear dimension the image scale of the telescope must be calculated. Image scale is usually expressed in degrees, minutes, or seconds of arc per inch or millimeter. To find the image scale in seconds of arc (arcsec) per millimeter, divide 206,265 (seconds of arc in 360 degrees) by the focal length (F.L.). For example, the image scale for a 10-inch (254mm) f/6 aperture telescope with a F.L. of 1524mm is:

image scale = 205,625 / 1524 = 134.7 arcsec / mm

Since many of the objects subtend very small angles, usually in the seconds of arc, we must increase the effective focal length (EFL) of our telescope to allow the image to be large enough to be separated by several increments. A large image also results in a higher resolution in the micrometer readings. The Barlow lens is a good way to accomplish this. If a 3x Barlow is used on the above telescope then the EFL will be:

EFL = 1524mm x 3 = 4572mm

With the increase in effective focal length the image scale then becomes:

image scale = 206,265 / 4572mm = 45.1 arcsec / mm.<![endif]>

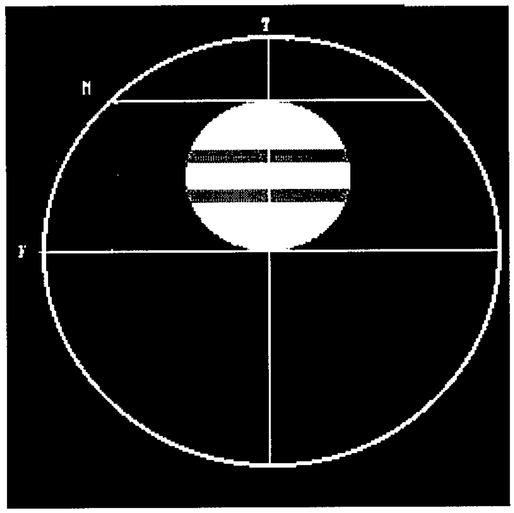


Figure 1. Jupiter as seen and measured in a Bi-filar micrometer. Show are three webs, 'T' for centerline, 'F' is the fixed web, and 'M' for movable web.

Let's use a micrometer to measure Jupiter from pole to pole. After the image is positioned between the webs or points at the focal plane the telescope drives are adjusted so the image just touches the north and south limbs of the planet. The separation is read from the micrometer dial or lines on the reticle and noted. You can find the separation by subtracting the micrometer "**zero**," that is, the dial reading where the webs or points are centered on each other. However, a more desirable way is to use the "**indirect-direct**" method. This method eliminates the need to use the micrometer "zero" and reduces any mechanical error by half.

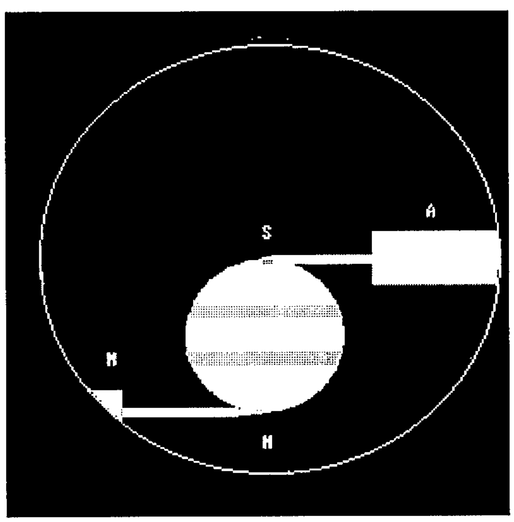


Figure 2. Jupiter as seen and measured in a needlepoint micrometer. 'A" is the fixed needle and 'M' is the movable needle.

The "indirect-direct" method is as follows: an object is positioned between the webs or points and a separation is read from the dial. Then the micrometer is adjusted so the web or points cross through the zero point (micrometer "zero") and the object is positioned

between the webs or points on the other side of "zero" and the dial is noted. The direct reading (smallest) is subtracted from the indirect reading (largest) and divided by 2. For the web type micrometer, the thickness of the web is subtracted from the result.

For example, if we measure the separation of Jupiter's poles using a web type Bi-filar micrometer with a web thickness of 0.012mm and read indirectly 12mm and directly 10mm -- the separation or linear size of Jupiter pole to pole is:

separation = (12 - 10) / 2 - .012 = 0.988mm

Given the above image scale of 45.1 arcsec/mm then the size of the image is:

size of image = 0.988 x 45.1 = 44.56 arcsec

If one should calculate, or look up in the Ephemeris, the apparentdiameter of Jupiter for that date they would find the polar diameter to be 44.56 seconds of arc. Of course, this usually doesn't happen in real life because of the difficulties involved with using a micrometer at the telescope in Earth's turbulent atmosphere. Even under perfect "seeing" the observer is compelled to use a deep red filter in conjunction with the micrometer to reduce atmospheric and irradiation effects. Irradiation of bright objects, especially planets in the eyepiece, is evidently a physiological effect, originating in the eye itself and occurs between adjoining areas of unequal brightness.

Also, the image seldom remains exactly positioned between the webs, points or lines of the micrometer and must constantly reposition the telescope slow motion controls. To reduce the observational systematic errors one must make many measurements during the observing period and average the readings.

If we were to measure the apparent size of the Great Red Spot (GRS) on Jupiter and desire to know how large it is with respect to the size of the Earth, then we find the relative size of the GRS to the disk of Jupiter and convert that to kilometers. The diameter of Jupiter is 142,984 kilometers, so, if we measure the apparent size of Jupiter to be 0.988mm or 44.56 arcsec by micrometer and measure the GRS to be 0.176mm or 7.94 arcsec, then the size of the GRS in kilometers is:

GRS = (3.98/44.56) x 142,984 = 25,471 km

The GRS is about twice the size of our 12,756km-diameter planet, Earth.

<![endif]>

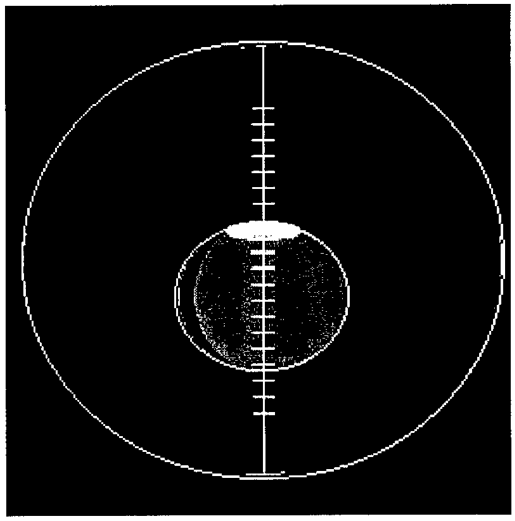


Figure 3. Reticle type eyepiece micrometer. Shows pole to pole diameter of Mars.

If we were to find the smallest feature on Mars using the above 10-inch telescope we must use the resolution of the telescope. If we use the theoretical Dawes limit of resolution, in inches = 4.56arcsec / aperture, or in millimeters = 115.8 / aperture, and find for the above aperture a resolution of: the above telescope:

resolution = 115.8 / 254mm
= 0.456 arcsec

For example, if we observe Mars at it's maximum apparent angle of 25.1 arcsec and want to know what the smallest feature we can see on the planet is, multiply the diameter of planet (6,787 kilometers) by the ratio of the it's resolution to the apparent angle of Mars at that time:

smallest feature = 6787 (0.456 / 25.1)
= 123.3km

Many planetary observers have found the Dawes limit too large and claim they can smaller features on planets. That is a subject for another article.

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